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D9.64 – Social and ethical aspects
linked to monitoring and modelling: a Socio-Technical Integration Research approach

Authors: Michiel Van Oudheusden (SCK•CEN, Belgium), Dolores Maëkivi, Keiu Telve, Kata Maria Metsar, Alan Tkaczyk (University of Tartu), Chloé Dierckx (University of Antwerp), Sergi López-Asensio, Roser Sala (CIEMAT), Erik Fisher (Arizona State University)

Reviewers: Kelly Jones (PHE), Marie Simon-Cornu (IRSN)
and
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Abstract

This report presents the research aims, methods, and outcomes of CONCERT sub-subtask 9.3.2.3 (Task 2.3 of the TERRITORIES project), based on lab/fieldwork conducted by lab engagement researchers (students and their supervisors) in three research laboratories: 1) Laboratory of Environmental Physics, University of Tartu (Estonia); 2) Biosphere Impact Studies group, Belgian Nuclear Research Centre SCK-CEN (Belgium); 3) Environmental Radioactivity and Radiological Surveillance Unit (Spain). The report makes explicit how, through social science intervention (socio-technical integration research; STIR), social and ethical considerations are, and can be, integrated into ongoing radiological protection research with the benefit of improving scientific modelling and assessment.

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1. Introduction

The research aims of CONCERT sub-subtask 9.3.2.3 (Task 2.3 of the TERRITORIES project) were: i) To identify how radiation protection researchers involved in the project (in particular WP1 and WP2) address and manage uncertainties through models and monitoring in long-lasting exposure situations; ii) To integrate social and ethical considerations into research in/on radiation and radiation protection. The study sought to bring insights into how and why social and ethical concerns can be integrated into ongoing research and development, with a strong focus on uncertainties in dose assessment and risk management. It also seeks to facilitate discussions about experiences, practices, possibilities and limitations with regard to integrating these concerns – from different fields of science, from fundamental and applied researchers, and from different research fields. This study gives a transdisciplinary character to research within the TERRITORIES project.

The approach employed in this subtask was laboratory engagement studies, through structured dialogues, participant observations and interviews, and document analysis. A decision protocol was used that enables social scientists to observe and interview radioecology and radiation protection experts involved in WP1 and tasks 2.1 and 2.2 of WP2 in their work environment (e.g. the laboratory) and ask them questions that allow for systematic, structured andrepeatable analysis.

2. Research approach and methods

The approach drawn on in TERRITORIES subtask 2.3 is called socio-technical integration research (STIR). It was developed by Erik Fisher (Arizona State University) and others with the aim of assessing and comparing the varying pressures on, and capacities for, laboratories to integrate broader societal considerations into their work. STIR is defined as "any process by which technical experts take into account the societal aspects of their work as an integral part of that work" (Fisher 2007).

Socio-technical integration is achieved by having an "embedded" social scientist or humanist interact with laboratory practitioners by closely following and documenting their research, attending laboratory meetings, holding regular interviews and collaboratively articulating decisions as they occur. He/she deploys a protocol that maps the evolution of research and helps feedback observation and analysis into the laboratory context itself (Fisher 2007). The protocol conceptually distinguishes four decision components: (a) opportunities, (b) considerations, (c) alternatives and (d) outcomes, as a means of identifying otherwise latent values, goals, and other considerations and creates opportunities to reflect upon the decisions at hand (Schuurbiers 2011).

To give an example of how the protocol is applied, when a discovery (e.g. an opportunity) is made in a lab, various considerations come into play that influence how the discovery is framed, received, and handled. These considerations may be of a *material* nature (physical, chemical, mechanical properties) and bound to finite resources (time, space, money); they may be of a *social* nature (laws, institutions, culture, group dynamics); or *human* nature (ethics, psychology, personal beliefs, interests). Within the STIR framework, these considerations are seen as uncertainties that often remain implicit or tacit, particularly as scientists become habituated in fixed modes of thinking, making it difficult for them to re-examine or question the assumptions, values, and societal aspects inherent in their work. Yet, these considerations at least partially shape the way the opportunities, issues, challenges, problems, etc. are managed in laboratories. The STIR researcher (social scientist/humanist) therefore intervenes to: (1) render scientists and technologists more aware of how these (and other) uncertainties shape ongoing research; (2) broaden the types of considerations that influence and construct research (e.g. by integrating social and ethical reflection into strategic decision making). These interventions may be characterized as "modulations" to the extent that they alter, adjust, or redirect ongoing research or technology development.

Through STIR initiatives, the protocol has been applied worldwide in various socio-technical fields (e.g. nanotechnology, biotechnology, neurotechnology, microbial engineering). Regular use of the protocol allows for collaborative exploration of the nature of research decisions, with the ultimate aim of shaping technological trajectories by rethinking the processes that help characterize them. Ideally, findings from such collaborations are disseminated to research participants and to decision makers (e.g. research managers, policy makers) to enhance joint reflection upon research decisions in light of broader considerations (see section 4). The current application of the STIR method constitutes the first time it will have been used in the context of radiological research, following the suggestion of Van Oudheusden et al. (2018).

3. Case analyses and findings (modulations) for the three cases

Three radiation protection cases were examined in detail by subtask 2.3 researchers. An overview of these cases is presented in table 1 below, along with the radiation protection field, the names of the lab engagement researchers (and their affiliations), and the anticipated start and end dates of their laboratory or fieldwork, and duration. The researchers in this subtask are BA, MA and PhD students with a background in the social sciences, ethnology and anthropology, and/or psychology.

Table 1. Overview of radiation protection cases, radiation protection field, lab engagement researchers, period and duration of lab/fieldwork.

Case (Country)	**Radiation protection field**	**Lab engagement researchers**	**Start and end date of lab/fieldwork and duration**
Laboratory of Environmental Physics, University of Tartu (Estonia)	Various (Radioecology; Applied Measurement Science; Atmospheric Physics; Analytical Chemistry)	Keiu Telve, Kata Maria Metsar, Dolores Mäekivi, Alan Tkaczyk (University of Tartu, Estonia)	2/01/2018 – 1/06/2018, 5 months
Biosphere Impact Studies (BIS), Belgian Nuclear Research Centre SCK-CEN (Belgium)	Radioecology	Chloé Dierckx (University of Antwerp, Belgium)	Between 28/02/2018 – 15/06/2018, 15 days
Environmental Radioactivity and Radiological Surveillance Unit (URAyVR) (Spain)	Environmental radioactivity	Sergi López-Asensio (CISOT-CIEMAT, Spain)	Between 01/05/2018 – 01/05/2019, 8 days

Each of these case studies is presented in detail below in the following format: (1) Research approach; (2) Case description; (3) Findings/Modulations; (4) Reflection on the STIR research process. As mentioned in section 2 above, research for this task was structured by way of a decision protocol and included a set of guiding research questions, which allowed lab engagement researchers to furnish their thoughts, impressions, and interpretations and relate their case study (laboratory or organization) to the overall objectives and interests of Subtask 2.3 of the TERRITORIES project.

Case 1: Laboratory of Environmental Physics, University of Tartu (Estonia)

1. Research approach: definitions, methods, and materials.

We combined ethnographic fieldwork with STIR-method. The fieldwork with the research participants lasted five months and the contact during the meetings continued for approximately a year. We interviewed all the team members at least once: at the beginning of the research period. We carried out 27 STIR sessions, with about 3-4 sessions with every participant.

We faced multiple challenges: (1) motivating the scientists to be engaged with Socio-Technical Integration Research within five months, (2) understanding the nuances of the research in Environmental Physics without having a background in the discipline, (3) creating trust between all parties and providing honest discussions to grasp the in-depth perspective towards the uncertainties. The risks were managed with constant communication and a flexible research model that did not disturb the scientists everyday work. This aspect is elaborated in subsection 4 below.

The fieldwork team are highly competent in developing and conducting social research. We have also participated in a workshop about lab engagement and training of the STIR protocol. We mapped the field and visited the workgroup meetings. There were no previous links with Environmental Physics, but we saw it as an advantage to be able to include an outsider's perspective.

As anthropologists and ethnologists, we started our research with broad research questions and purposely tried to avoid entering the field with preliminary hypotheses. This enabled the findings to speak to us and surprise us without being strongly framed by any preliminary convictions. It is also quite common that the focus of research questions changes over time as new material and ideas appear during the fieldwork.

Our research questions were:

1. How do the sub-discipline and the individual values impact uncertainty?
2. What kind of decisions are made during the research for TERRITORIES project?
3. Which considerations influence the decision-making?
4. What is the outcome of the Socio-Technical Integration Research?

2. Detailed case description.

Investigator(s): Keiu Telve, Kata Maria Metsar, Dolores Mäekivi, Alan Tkaczyk

Laboratory/research organization: Laboratory of Environmental Physics, University of Tartu

Address: Institute of Physics, University of Tartu, W. Ostwaldi Str 1, 50411, Tartu, Estonia

Start and end date of lab/fieldwork and duration: 2.01.2018 – 1.06.2018, 5 months

The case discussed here is a collaboration inside an interdisciplinary team from the University of Tartu brought together for TERRITORIES project. The objectives of the organization in EU TERRITORIES project is devoted to the characterization and improvement of computational models of radioecology which predict radioactive pollution spread in case of accidents and/or describe the slow evolution of quasi stationary status of radioactively contaminated (polluted) territories. The basic task is to critically review and characterize the models, uncertainty calculations methods and to provide reliable and possibly universal guidance on uncertainty estimation.

The team includes 8 scientists from four disciplines: Radioecology group; Applied Measurement Science (uncertainties); Atmospheric Physics and Analytical Chemistry.

The case was developed as part of TERRITORIES project Task 2.3 and aimed to understand social and ethical aspects linked to uncertainty in modelling. It develops the scientists' reflexive perspective towards every step of their decision making and also helps to raise social awareness of their work.

The case study involved observing all the activities in the Estonian team for the project TERRITORIES. We concentrated on how they analyzed sensitivity of improved models (task 1.3) and selected the appropriate level of complexity in models (task 1.2).

The basic problems of current radio-ecological modelling were:

- The accuracy of the models predictions is rather low and model comparison exercises have shown that abilities of models differ greatly.
- There are different approaches on how to calculate the uncertainty of the radioecology models but there is no generally accepted method.
- The shift from deterministic model calculations (where the model has single output value for every endpoint) has shifted in the direction of probabilistic approach, which allows a probability distribution function for every endpoint to be found, allowing to estimate the uncertainties. The difficulty has shifted to finding appropriate statistical distributions of input parameters.
- There are multiple models available for radioecology but there is no commonly respected model or method which could be used in the case of accidents for risk estimation.

There were technical, material and social uncertainties that influenced decision makers.

- Technical: What programs to use for conducting the research? How to include uncertainties so that it would embrace the reality? What should be the level of the generalization?
- Material: Where and how to get reliable samples to analyze the sensitivity of the improved models?
- Social: How are the research values impacted by the researcher's background? How often do disciplinary differences occur in the team-work? How are the research values impacted by the age, the previous scientific career, the different school of thought? What is the role of individual values and researcher's personal character on ongoing research?

3. Findings (modulations).

De facto modulation	Reflexive modulation	Deliberate modulation
Interdisciplinary workgroup Research participants are working in an interdisciplinary team, which enables them to use knowledge from different fields in order to solve research problems.	One of the team members needs to decide which statistical formulas to use in order to compare measurement data with calculated data. During the first STIR interview he comes to an idea to implement formulas from air pollution studies (his usual field of study) to radioecology. D: *So if it succeeds, would it be possible that radioecologists start to use this methodology in their work?* *M: Yes, I think it is, I think it could be one of our missions in this project.* Modulation occured because STIR researcher kept asking for alternatives to approach this problem of finding suitable formulas. Then he said that he could try to use the methodology of air pollution studies.	Time goes by and during the next STIR sessions we discuss the problems with getting enough measurement data to apply statistical formulas. He works on comparing the data which is collected from different contaminated areas. Finally he receives a good amount of data from Norwegian partners and tries to use statistical formulas from air pollution studies to this data. He finds out that measurement data in radioecology field is not homogeneous enough to use those formulas for analysing it. He admits that he really wanted to bring something from his own field to radioecology but it did not work out. So deliberate modulation occurred in the form of value deliberation, although he was not able to implement the idea (in the form of a practical adjustment).
Working on a topic which affects people and environment Research participants are working in the framework of an applied scientific project which purpose is to make radioecological models more accurate in order to make our living environment safer.	During the first STIR session with one of the interviewees, theSTIR researcher asked for the wider impact of his work assignments every time he mentioned a new task. *M: We need to understand why do models underestimate risks. Because when we overestimate then it's not too bad but if we underestimate then it could be dangerous.* *D: So what's the wider importance of that?* *M: It's important for human health and environment. This is one main reason why we work in this project, so that our environment could be safe for humans and wildlife.*	As time passed by he started to bring out the importance of his tasks without asking, as seen from the example below. So it can be considered as value deliberation and change in discourse. *M: So I'm going to Madrid to find out if we can use their model to study processes in Fukushima. It's actually a very important in a practical sense, to study Fukushima case, because pollution goes from atmosphere to trees not other way around.* This modulation occured because he got used to the questions about the importance of his work, so he started to think and talk about this more and also initiating the topic himself.

Applied project is a possibility to show the need for science TERRITORIES project is dealing with practical issues which have an impact on human health. There's a great opportunity that research results are going to be applied in order to make living environment safer. This way there's a chance to improve the image of physics.	During STIR interviews research participants often comment that their work is not valued in society and it's difficult to make themselves heard. One of the interviewees talks especially about the consequences of his work and he feels social responsibility greatly. He is also concerned about poor knowledge of physics among young people. Difficulties and opportunities for making science popular were discussed a lot during the STIR sessions. STIR researcher and interviewee generated ideas together how to solve this problem. STIR sessions made him think more about this topic and helped him to consider possibilities to address wider public with his research results. It seemed like it was the first time he thought about some of the ideas that were discussed. We can say that STIR sessions gave him motivation and it can be therefore seen as a value deliberation. *In this quote he acknowledges the usefulness of STIR sessions:* *K: So do you think these STIR sessions are helpful for you?* *R: Of course, because if I talk about those things it makes me think about them and that's how I can come up with new ideas.*	As a consequence of the STIR interviews he came up with an idea to write an article to the Southern-Estonian local daily newspaper about radon because it has a health effect on locals. He is still working on it. This modulation occured because he was working on the topic which affects the wider public and as we had recently discussed the ways on how to make scientists heard, he got an idea to write the article for people to read.

Different motivations inside the workgroup The workgroup consists of members with different research backgrounds which leads to different opinions about conducting the study and publishing the results.	It's the task of the head of the research group to manage different opinions and find the solutions that fits everybody. During one of the STIR sessions with him we were discussing the problem that some of the team members don't want to participate in writing scientific articles, instead they would prefer to focus on the project report. We started to discuss the importance of articles and he got some ideas on how to convince group members that articles are important for them. He wrote some things down and said that he's going to use these ideas next time he is talking to group members. *D: So what's the consequence of not writing any articles?* *A: There's a lot of benefits of writing them. As the leader of the WP2 said that articles are also very important* *D: So it's also about your reputation in front of foreign partners?* *A: Yes, of course. This is actually a very good argument. I'm going to use it to convince M.*	It revealed during the participant observation at the work group meeting that the head of the group managed to convince everybody individually that publishing articles is important for the group as well as everybody individually. Also one of the members told the STIR researcher during one interview that the head talked to him about this topic and used the same arguments which were generated during the STIR sessions. From that moment on we didn't hear any complaining at the meetings about concentrating on articles. Everybody seemed to have acknowledged the importance and decided to contribute to publishing articles This modulation occured because we were discussing the topic which was on the agenda at the moment and so he had an opportunity to bring these ideas into practice immediately.
Changes in research plans At first research group had an idea to write one scientific article together with whole group. This article would have been an overview article about radioecological models.	At the beginning everybody seemed to think that it's a good idea but as time passed by several team members started to express doubts about their capacity to write this kind of overview article. They felt that they don't have enough knowledge about this field and so this task goes beyond their ability. *D: What are you working on right now?* *K: Well A wants us to write an article. But I think we need to make few small articles instead of one big one because I think we don't manage to do this overview article.*	As the result of feeling incompetent to write an overview article they changed their plans and decided to do several smaller articles. They made this decision during the workgroup meeting. STIR researchers notes from the meeting: *They are discussing if they should write one big or several smaller articles. They prefer several articles because this way there's more credit for the authors. Also they can later write larger article based on these smaller texts.* This modulation occured because they discussed this topic individually with STIR researchers and later on altogether. This helped them to come to a decision to change research plans.

International collaboration Research participants are working under the project which involves scientists from different European countries and therefore makes it possible to collaborate and share knowledge with professionals from respected research institutions.	Research participants are having difficulties with the lack of information or measurement data. Discussing the alternatives to approach this problem, one of the interviewees acknowledged that international network can be helpful and that he should contact other project partners in order to get more data/information. But he felt insecure about writing to foreign partners, as he said, he was afraid that he would seem incompetent. M: *Maybe the best thing to do would be to contact with other parties.* *K: From Territories project?* *M: Yes, but it's difficult because it's bit weird to say that please recommend a suitable model or give as data.* *K: But why is it weird?* *M: Well it leaves an incompetent impression of us.*	But as STIR researcher found out at the next meeting he still decided to reach out for more information from partners, contacting them in relation to his research problems. He did not talk about being afraid of seeming incompetent anymore. This modulation occured because he really needed help with his research and during STIR session he acknowledged that contacting foreign partners could be useful.
Getting research data from the country which is far away. One of the research participants is studying the contaminated area in Kazakhstan and how contamination affects locals behaviour. He's having a problem with questioning people who live so far away and he's trying to find a way to conduct research about a place which is so far away. He would like to travel to Kazakhstan but there's not enough money in the project to cover the travel costs.	Discussing the alternatives for approaching this problem during the STIR session, STIR researcher proposes the idea to apply for the money from different institutions. He said that it could be one option and he wrote this idea down for himself. He said he's going to look into it.	Between the STIR meetings he started to work on this problem but decided not to apply for the money but instead to conduct a web survey for locals to fill through internet. Additionally, he found some researchers from Kazakhstan who are going to conduct some face-to-face interviews for him. So the discussion with STIR researcher motivated him to take action in order to collect data from Kazakhstan. Even though he did not stay with an idea he got from the STIR session he still reacted to the brainstorming and started to work on this problem.

Group members are not experts on radioecology field Scientists working on this project have a different research background and radioecology is a new field for some of them	One of the research participants feels insecure about his knowledge in radioecology and he could use more help regarding with individual research, especially with mathematical part. While discussing the opportunities to get more help he starts to think about finding another partner from the work group. *M: I feel like I'm quite inexperienced regarding to radioecology field.* *K: But is there anyone in Estonia who is a specialist in this field?* *M: Well, I don't know about Estonia.. I think only option is to look at our group.*	Soon after this STIR session he managed to find him a partner inside the work group. He also contacted a mathematician who is not part of the team and got a lot of help from him. This modulation occurred because he got to discuss the option he have and decided to take action and find help.

4. Reflection on the research process.

We combined STIR method with in-depth interviews and participant observations. We believe that this is the best way to gather information. At first, we conducted one in-depth interview with research participants, which helped us to understand their research background and their motivations. We also participated at the work group meetings in order to understand group dynamics and research progress. This was very useful for understanding deliberate modulations because attending the meetings enabled us to see which ideas they have really taken into practice. We recommend combining STIR with other research methods in order to get the best overview.

In general, research participants received our approach well, although there was also some confusion. For example, one of the interviewees admitted at the end of the STIR sessions that STIR researchers had not recommended him any solutions regarding to his research problems. In this case, the interviewees needed help with mathematical problems but it is clear that a social scientist is not able to help in this field. Sometimes our questions did not lead to ideas because research participants did not have enough knowledge about radioecology to come up with solutions.

One difficulty we faced doing STIR interviews was to keep up with terminology of another discipline. At the beginning, it was hard to understand their research agenda and so a lot of energy and time went to this. It also led us to discuss more “soft“ topics and less about research details.

We also faced the problem noticing occurring modulations. One of the reasons is that every single STIR session is focusing on different research problems but modulations assume observing the same problem through a longer period of time. Only this way it is possible to observe if scientists have made any changes in their work. This is of course different to a laboratory experiment where ideas can be put into practice immediately.

Seeing the outcomes of STIR research would have also been easier if we had a control group. Splitting the research group to two, one with scientists who have taken part in STIR meetings and one with those who have not. This would have enabled us to see if STIR has really had an effect.

We think it is also important to consider that all the research participants are individuals with different backgrounds. For example if STIR is conducted with a scientist who is a foreigner and lives in another city, it is very difficult to know what made him make some decisions and what else might have influenced him in addition to the STIR sessions.

Another one of our observations is that the best way to conduct a STIR interview is face-to-face. We tried through Skype a few times but it was extremely hard to motivate interviewees to talk and for us to make notes. Technical problems made it also very difficult to concentrate on STIR.

In conclusion, it can be said that STIR sessions made research participants think more thoroughly and this helped them to come up with new ideas. In our experience, it is useful to combine STIR with other methods in order to get best research results.

Case 2: Biosphere Impact Studies (BIS), Belgian Nuclear Research Centre SCK-CEN (Belgium)

1. Research approach and methodology.

The research combined the STIR method with participant observation. From March until June 2018, the researcher spent on average one day each two weeks at the research site and followed one scientist hereafter referred to as 'the participant'. She worked in the same office as the participant and joined one fieldtrip. At the start of the research period, some exploratory conversations took place so the researcher could get familiar with the work of the participant. Some of these conversations were formal while others happened in a more informal way e.g. during the fieldtrip. The STIR protocol was used only once during an interview, but since both researcher and participant were well aware of the questions guiding the protocol they later on spontaneously came up during informal conversations while spending time together in the office. We both felt that the use of the protocol 'in motion' was more natural and allowed for the questions to be directly connected to the work being done at that exact moment. As opposed to going back in time during an interview after the facts, it allowed registration of some thoughts of the participant as they came up. The ability to spend a full day in the same office was thus very beneficial.

2. Case description.

The research took place at a research centre specialized in peaceful applications of nuclear energy. The site focusses on risk reduction, determining radiation limits and developing models to predict radiation effects. The main task of the participant during the research was to build a model that can predict the effects of radiation on an ecological forest system.

The research was aimed at better understanding uncertainties in nuclear science and, by using the STIR method, to strengthen the awareness of scientists of social and ethical issues related to their research. The participant identified three types of uncertainty he is confronted with in his work:

- Measurement uncertainty: related to the tools used to collect data - each tool has its margin of error.
- Conceptual uncertainty: related to researcher himself - how to be sure he is interpreting the data correctly and applying the right equations?
- Uncertainty in result communication: related to the communication between researchers, stakeholders and government - How to define what is a risk and what risks are acceptable or not?

The participant indicated that, for the uncertainty in result communication, the involvement of social scientists can be crucial since they can form a link between scientists and the government and can help to decide when something is considered a risk. Therefore, most of our conversations focused on this last type of uncertainty.

Because the site focusses on peaceful applications of nuclear energy, its consideration of societal implications is high, both considering the benefits of the research and the perceptions of risks related to radioactivity. The participant showed a high awareness of the societal impact his research can have but also of the impact of societal factors on his research, both content wise: what research proposals are funded? and process wise; who should be consulted and involved during the research?

3. Findings (modulations).

This chapter describes the findings of the research starting from four de facto modulations present at the site and the related reflexive and deliberate modulations if they occurred.

3.1 Uncertainty of the model itself

De Facto: A model can never offer complete certainty, the modeler should decide what factors to include in order to achieve a balance between simplicity and accuracy, so the model can still be used by non-experts and serve its purpose. There seems to be a recurring problem that stakeholders expect models to be completely accurate which might lead to unrealistic expectations.

> *'Any model has to be limited somewhere. There is a parabolic function where the quality of the model can go down again when it becomes too complex. The required amount of complexity depends on the use of the model. It is important to consider the end users needs.'*

Reflexive: During a meeting in which the participant explained the model he was working on to the researcher, she asked him some questions about why certain factors were included while others where not. This made him consider including an extra factor to the model.

Deliberate: The week after the meeting, the participant decided to add the extra factor to the model, as he explained in an email:

> *On Monday when you came (…) something interesting happened when I was showing you the forest model. You asked why there was no exchange between river and atmosphere, it's something I had not thought about. But today I did it, I modified the model.*
>
> *From atmosphere to river there is now a flux of water (rain) and entry of contaminants, I was able to use the same equations that the model uses for deposition on tree surface. (...) For evaporation of water I found a formula which requires a "pan coefficient" for evaporation from a shallow river or lake.*
>
> *So in total I gained a new improvement to the model with addition of only one parameter (the pan coefficient).*

Conclusion: Considering the difficulty in finding the right balance as mentioned in the de facto modulation, the conversation with a non-expert offered the participant some feedback on which factors could be included to maintain simplicity yet reach higher accuracy.

3.2 Power relations in research funding

De facto: A lot of scientific research depends on governmental funds. It is therefore important to live up to the expectations of funders and give confidence. During a conversation about a presentation the participant will be giving to funders of the research he is working on, he shows his concern about what to present. The presentation needs to give the impression 'they are fulfilling the contract'. For this he will first need to understand what the funders 'understand as progress.'

Reflexive: Later conversations between the researcher and participant about funding and research proposals evolve to a questioning of the power relations between scientists, stakeholders and funders. Because of the strong dependence on governmental funds, which in turn often depend on public opinion, it is important that the government knows what type of research is important, both from the point of view of stakeholders and of researchers.

> *'The question is who is deciding where the money goes to, are the decision makers influenced by the scientist, are vice versa? Is the public influencing the government or is the government telling the public what to find important?'*

He questions the urgency of some of the research that is being carried out, such as for example the large amount of research that focusses on defining radiation limits more and more precise:

> *'Since a model is always somewhat uncertain, it needs to be accepted it is impossible to offer full certainty. Therefor at some point it becomes a waste of project money to try to reduce uncertainty even further. There needs to be a dialogue with the public to see what their concerns are and to help define the boundaries.'*

Conclusion: Though there has not been a deliberate modulation, throughout time there has been a discursive shift considering power relations in research funding. It is possible this shift happened because the participant reflected more on the subject, but it is equally possible that growing trust between the researcher and participant allowed for a more critical attitude concerning certain subjects.

3.3 Lack of fundamental research

De facto: Following from the governmental impact on the type of research that can be carried out, a lot of funding goes to research that focusses on short term impact, because of the short political terms and research that is human centered. The participant beliefs that there therefore is a lack of research on the long-term impact of radiation and impact on entities that humans feel less related to or impacted by such as marine life. He believes more direct involvement of lay people would lead to more fundamental research because people in general are curious about how things work.

> *'Often, the more general the public is, the more interested they are in fundamental things. They want to know about plants and animals and they don't believe you if you say "the maximum dose is x mc", they want to know what is behind everything.'*

Reflexive: At the end of the research period the participant is thinking about organizing a conference on radiation effects on marine ecology together with a colleague. This conference should be directed at politicians, so they can become aware of the importance of the long-term effects on marine life. An important aspect of the conference is that is should take place next to the sea, so participants can directly relate the subject to their environment.

Conclusion: Though it is hard to know what factors influenced the decision of the participant to think about organizing a conference, throughout the research period there is a progress in dealing with the way politics influences research. While there was a clear worry about power relations in the beginning, at the end of the period, the participant took an active approach to partly solve one of the consequences of this problem, namely the lack of research of marine ecological research. He also shows a great awareness of how best to involve non-experts by thinking about the sensorial impact of the environment of the conference.

3.4 Communication balance

De facto: A recurring concern of the participant is how to effectively communicate research results to a non-expert public, since this might establish a better understanding between all parties.

Reflexive: During the research period a lot of effort went into finetuning a presentation for a conference that also invited stakeholders and lay people. The difficulty thereby being what information to select and what information to delete. Though as mentioned earlier, transparent communication towards the public is considered important by the participant, in order to keep it understandable for people without background knowledge, some things had to be left out or simplified. We further discussed this difficulty after the conference where the participant joined a workshop on stakeholder involvement:

> *'It was mentioned during the workshop that there is a risk of overinforming the public, so they are not reassured but will get worried about things they should not worry about and later on confront you "why did you make us worry for nothing?"'*

Deliberate: During the preparations for a presentation to lay people, the researcher and participant went through the slides together. Based on how the researcher -as non-expert- understood the slides, some changes were made such as deleting formulas and adding pictures.

Conclusion: Both de facto and reflexive modulation emphasize the need for a communication balance or thorough consideration of knowledge translation in order to overcome the uncertainties in research communication. As mentioned in the beginning of the report it is mainly in this instance that the involvement of social scientists is important.

4. Reflection on the research process.

Throughout the research period, there have been some modulations which show a change in awareness of impact of research on stakeholders and non-experts and vice versa the societal and political impact on research and how to deal with these issues. It should be noted however that the participant was already very much aware of the societal relevance of his work and these changes might thus also just be a result of growing trust between the researcher and participant or a time-based concretization of his ideas, his participation in a related conference etc.

Some deliberate modulations such as the adaptation of the model and the slides for a presentation clearly happened as a direct result from the presence of the researcher, mainly because of her being a non-expert and asking a lot of questions about the meaning of things and reasons behind certain decisions.

The STIR protocol overall proved to be a useful tool to reflect upon the reasoning behind certain decisions. In this specific case, because the participant was already very reflective on the societal implications of his research, I believe the method was mainly useful to become aware of this reasoning and structure related ideas rather that cause a higher degree of reflexivity. However, the logging and structuring of these thoughts might well have enabled the participant to organize his ideas better and give him a more clear view on which actions to undertake.

Case 3: Environmental Radioactivity and Radiological Surveillance Unit (URAyVR) (Spain)

1. Research approach and methods.

The case study involved the application of the STIR method combined with qualitative analysis tools (specifically, interviews via video conference or phone calls). The aim was to understand: (i) How natural scientists consider social aspects in their daily work; (ii) which are the main uncertainties they have to face; (iii) how they can integrate the social aspects in their research.

We contacted three people in the Unit “Environmental Radioactivity and Radiological Surveillance Unit” (URAyVR) from CIEMAT. On one hand, we contacted with the head of the unit and he was interviewed once, only to obtain contextual information about their Unit. On the other hand, two researchers formed our sample for the STIR protocol application. Both of them hold a PhD in Chemical Sciences, and the first one (Researcher 1) is the head of “Laboratory 4” while the other one (Researcher 2) is the head of “Laboratory 3”. The fieldwork lasted from May 2018 to May 2019. Both researchers were interviewed once for introductory questions. For the application of the STIR method “Researcher 1” was interviewed twice while “Researcher 2” was interviewed three times.

In this case study, the STIR method could not be applied with face-to-face observation, in its genuine form, due to the physical distance between the studied unit, based in Madrid and our team, based in Barcelona. Some challenges emerged from this situation like trying to immerse ourselves in a laboratory

without being actually there. Other challenges not related with the distance but with the STIR method itself were: understanding the nature of their work from our social sciences background, achieving a good level of trust with the participants, and being clear and concise with our objectives in order they were fully understood.

To clearly understand the observed team, we started with a preliminary search of their lab activities published on their website trying to establish a first contextual frame of their duties. After this, we interviewed the head of the unit who gave us detailed information about the composition of their team, their main areas of expertise, their objectives and the development of their daily work.

Then, we arranged a meeting with two different researchers to discuss two or three issues and apply the STIR protocol. After these first meetings, we arranged secondary meetings a few weeks later, encouraging the interviewees to think about the issues discussed in the time between the meetings. During these secondary meetings, we discussed deeply the issues that appeared in the first session and we applied the STIR protocol in an iterative way. We continued the interview sessions until we considered the STIR protocol was fully applied. All the interactions were audio recorded in order to better analyse them.

2. Detailed case description.

The organization studied is the "Environmental Radioactivity and Radiological Surveillance Unit" (URAyVR). They are an environmental radioactivity analysis laboratory and they are part of the Division of Radiological Environment of CIEMAT's Department of Environment. Seventeen people whose backgrounds are mainly related to chemistry, biology and lab techniciansmake up the lab.

They develop their activity in three fundamental areas. The first one, considered the most important and their main purpose, is to carry out an environmental radiological surveillance program at CIEMAT. This surveillance programme is required by law due to the nuclear activity that CIEMAT carried out in the past. Taking advantage of this infrastructure, they developed a second activity consisting in measuring radiological affected areas for a number of different customers. Their third area is basic research, which is focused on the development of new methodologies.

The laboratory does not have a direct relationship with lay citizens because they only have a relationship with its customers (companies). Their reports are submitted immediately to the Nuclear Safety Council (CSN), who informs the parliament and publishes an annual report. Their only contact with the public is through the unit's website that is visited from countries all over the world when the reports are published, according to them.

3. Findings.

3.1. Funding

De facto: The participants in the team feel they are not receiving enough government funding. They affirm that in Spain, the only body that funds environmental radioactivity research is CSN. They think this situation causes that many managers of scientific institutions to see them as scientists working on something but without importance or impact.

Reflexive: In a later conversation, the participant (2) thinks that an alternative to change this is to try to fight for themselves.

> *"The solution is very simple. Work for free and publish in scientific journals to become obvious."*

Funding also goes through trying to find applications of their work in other fields and try to turn this into support techniques for other projects.

> *"Moreover, I think that what you have to look for are applications in other fields. See if they can be converted into support techniques for other projects."*

3.2. Human resources

De facto: Both participants suggest there is a problem with the lack of staff in their departments and they affirm it is detrimental to the scientific quality of their laboratories.

Reflexive: In a later conversation, the participant (2) affirms the only possibility to get more staff is obtaining funding through projects.

> *"To have staff, you need projects."*

The participant also suggests that the social attention the topic has is a key factor to have more projects and therefore, more funding.

> *"As soon as there is some interest, as there is for example with this subject, there will be more staff."*

3.3. Lack of objectives

De facto: The participant (2) thinks there are no clear objectives for science in Spain. He feels that everyone works in the projects they want without a long-term roadmap.

Reflexive: In a later conversation, the participant thinks that a solution could be that instead of researchers ask the government for funds, that the government itself has to take the initiative and ask the scientists to work for them.

> *"It is very good that people ask for projects, but I believe that the Spanish Government also has to search for good scientists and finance them."*

Deliberate: Later he affirms that a possible solution could be to create a team of government scientists organising public research and giving priority to the fields that need more funding or are more important in a certain time.

> *"These scientists have to be visible and give priority to what is more needed in the scientific field. For example, if a research field is not interesting in a certain time or whatever, the scientists should ask this person if he/she can change to another investigation or whatever is needed."*

3.4. The future of the scientific system

De facto: The participant (2) thinks the patent system in Spain is full of obstacles, with a very long process needed to register a patent. From his point of view, the patent system in the United States works very well and it can be a good example.

"In the United States, what they do is to set up a perfect, easy, agile and very simple patent system for scientists. Therefore, if I find something, I patent it."

Reflexive: In another conversation, the participant suggested that in Spain there are very good scientists and very fresh ideas in science but usually are restrained by bureaucracy. Therefore, he suggests that a better framework is needed.

> *"Therefore, what is needed is the framework that originally set Zapatero's [former Spanish president] Science Act. We need to introduce it."*

Later, the participant affirms that science in Spain is utopic. He affirms that many people think that science should not be sold but the participant is opposed to this idea.

> *"For example, the US system is based on the investigation, patent and earning money."*

Deliberate: Later, he suggested that science has to be "sold". He says that Spain developed solar power but is Germany who is patenting it. He thinks science has to be practical and serve the community in a very broad sense. He expresses that selling science can be beneficial for both science and the public, resulting in more public and private funding.

> *"If the public sees an income from science and private companies see, for example, that public entities are able to solve problems, they will finance public research. But if there is no such thing, there will be nothing."*

The participant suggests that a free patent system for the scientists could be economically profitable for the government and even become self-sufficient.

> *"If there is a patent system that is almost free for a scientist, then the Spanish Government could even earn money, then it can start to reinvest this money in science and it could even become self-sufficient."*

3.5. Lack of collaboration between departments

De facto: The participant (1) express concern about a lack of cooperation among different departments.

> *"There is a lack of personal interest among departments to manage shared projects."*

Reflexive: In a later conversation, the participant suggests the situation is affecting various teams, increasing the lack of motivation, and therefore, with more researchers leaving to other departments.

> *"There are researchers that are leaving to other departments or institutions due to a lack of incentives."*

3.6. Social visibility

De facto: Discussing the relationship between natural sciences and the lay public, a participant (1), recognizes the management is aware of the need to build up better communication. Nevertheless, scientists feel abandoned.

> *"They show us that it is very important to be prominent. We have to write our own news, we have to show interest to be known by society but that effort has no real support."*

Reflexive: In another conversation, the participant thinks about this idea of social visibility. She recognizes that this kind of social uncertainties can only be addressed increasing and sharing the knowledge with lay people.

> *"Social uncertainties can only be addressed by increasing the knowledge of social groups."*

After this, she suggests they cannot be responsible for this task and shares a possible solution.

> *"There must be scientific professionals responsible for the popularization of science."*

Deliberate: In another conversation, the participant (2) remembers that a vocational training intern started to talk about their duties in the laboratory with classmates and they were enthusiastic by his work. The participant thinks this can be a way to increase their visibility.

> *"Step by step. Last year we had a vocational training student doing an internship and in the faculty, he already started talking about us. He said, look at what they do, how cool is it. That has to be spread."*

He also suggests that TV series and movies are an interesting tool to increase the knowledge and visibility of a topic for the lay public. Although he affirms that for him is more important to be known in academic and scientific fields.

> *"Nowadays everyone is starting to know what radioactivity is because of Chernobyl TV series that everybody is watching now."*

4. Discussion/Reflection.

We had to combine the STIR method with other qualitative tools like semi-structured interviews to achieve a good data collection without being in the laboratory. Both participants received this approach and their selection as participants in a positive way. However, we found several difficulties. The most important was the application of the STIR method via phone or video conference. It proved to be difficult to motivate the participants on a regular basis. Usually, they were overloaded with work and they had to find time to give interviews although this did not affect their high level of interest in it.

We think that our methodology had some difficulties in obtaining relevant information. We had to rely on their words, as we cannot observe, and the application of the protocol was not as natural as if there had been an embedded humanist in the lab. On the other hand, it would have been impossible to do this case study without this mixed methodology, so we still assess it in a very positive way.

Noticing the modulations while they occurred was difficult and possibly increased due to interviewing by phone. The Decision Protocol was a great tool to address this problem during and after every session. After every session, we listened and transcribed the interviews and we analysed them in order to get information. Before the following interview, this information was analysed and this let us know and structure the most relevant topics to modulate during the following session.

During the research process, some modulations evolved from de facto to reflexive and from reflexive to deliberate. Although that last evolution was more difficult to achieve, it occurred osome occasions. The researchers showed a change of awareness and attention to the societal aspects involving their research. Most of the time the participants were aware of the social challenges their work faces, but the STIR sessions helped them to think more about these challenges and bring up solutions or changes that without these sessions probably would have not occurred.

To conclude it can be said that the STIR sessions contributed to raising awareness of the social aspects involving natural sciences and to strengthen the perception of the social aspects among participants.

4. General discussion/Reflection

The main conclusion of subtask 2.3 of the TERRITORIES Project is that the STIR collaborations made research participants think more thoroughly, come up with new ideas, and improve their scientific practices. The STIR sessions also helped participants identify and think through different forms of uncertainty, including measurement uncertainty, conceptual uncertainty, and communication uncertainty.

Feedback obtained from fieldwork participants and TERRITORIES project members on subtask 2.3 (e.g., at TERRITORIES meetings and conferences) suggest a positive reception of this research across the three cases. Various research participants emphasized the value of 'broadening' the types of considerations that go into their research activities, with one participant exclaiming that, "[STIR] got me thinking about the bigger world in which science fits into." Participants also appreciated the collaborative character of STIR, enabling technical and social experts to learn from one another. For instance, one project member stated that a broad-based social knowledge was valuable to him because it is distinct from the more narrowly specialised, technical knowledge of scientific experts. Social scientists, in turn, noted that many of the researchers they interacted with are well aware of the constraints within which they are working, such as "limited budgets" and "policy dictates."

In two cases, participants stressed that the mere presence of a social scientist in the lab can have a benign influence, particularly as scientists usually work individually. STIR offers them an opportunity to discuss their work to an outsider, which may (indirectly) improve not only the quality of their work but also their work satisfaction.

The three cases of TERRITORIES subtask 2.3 employed the STIR protocol in three distinctly different ways, which provides an opportunity for comparative learning. Protocol use varied across the three cases in terms of social science input, interdisciplinary interaction, and content of the communication. Specifically, Case 1 used a "high" deployment of the protocol, Case 2 utilized a "low" deployment, and Case 3 deployed it more closely in the manner of an interview schedule (see Table 2).

Table 2. Protocol use and modulations per case study.

		MODULATIONS**		
		Learning	**Deliberation**	**Adjustment**
PROTOCOL USE*	**High**	Yes	Yes	Yes
	Low	Yes	Yes	Yes
	No	Yes	?	No

* Protocol use is described by three determinants: Input (usually in the form of questions); Interaction (dialogue, conversation, extractive interview); and Content (subject matter). Protocol use is considered "high" when Inputs take the form of questions *structured* by the protocol's four conceptual components; when Interaction takes the form of intensive dialogue; and when Content is derived from the immediate experience and practices of the participant.

** The cases refer to two types of social science-induced modulation: reflexive modulation and deliberate modulation. However, following Fisher and Schuurbiers (2013), modulations can be specified in more detail, as: reflexive learning ("learning"), value deliberation ("deliberation"), and practical adjustments ("adjustment").

Limitations of the STIR approach relate to its qualitative research design and implementation. The approach can be time consuming and requires a well-trained researcher, who is accustomed to using STIR methods and tools (i.e., decision protocol). It also takes time to build trust with research participants so as to facilitate full and honest conversation. The aims of the research study are not always clear from the outset, as research questions, topics, and findings are developed inductively, through ongoing interactions between researchers and interviewees.

Suggestions for future work in this area include:

- Incentivizing collaborative, interdisciplinary research by initiating follow-up STIR studies and by encouraging interdisciplinary collaboration in general. Whereas interdisciplinary research is now acknowledged to be an increasingly important aspect of the scientific profession, many technical researchers and social scientists do not have the time and resources to commit to interdisciplinary work.
- Maximizing the impact of STIR: (a) *inside* the lab by lengthening the duration of STIR studies and by facilitating access of social scientists to the labs and lab researchers; (b) *across* scientific management levels by increasing communications at early stages, as STIR modulations occur (for instance to the project management board); (c) *outside* the lab research process by combining the STIR approach with other social science interventions, such as focus groups and stakeholder panels.
- Acknowledging the strengths and weaknesses of STIR. This includes recognizing the specificity of STIR as a lab-level, research-project focused approach that is distinct from other social science approaches, such as risk communication, public engagement, and science policy studies, to give a few examples.

Subtask 2.3 of the TERRITORIES Project is a proof of concept, illustrating the potential of socio-technical integration research (STIR) to enhance reflexive awareness among technical and social scientists of the uncertainties that accompany radiation protection research, specifically in the processes of modelling and dose and risk assessment. These uncertainties are of a technical nature and bound up with various 'non-technical' considerations – economic, social, ethical, psychological, etc.

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